# SOLUBILITY CURVES OF INORGANIC PHOSPHORUS IN THE PADDY SOILS OF TAIWAN

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In Taiwan, due to the difference of climate, parent material of soils or local topograph, the paddy soils may be classified into six groups: namely, (1) the sandstone and shale alluvial soils, (2) the slate alluvial soils, (3) the schist alluvial soils, (4) the mudstone alluvial soils, (5) the saline alluvial soils, and (6) the red or yellow earth. The responses of phosphates on these main soil groups are different from each other.

Generally, the inorganic phosphorus in the soils are combining with iron, aluminum and calcium to form a variety of compounds commonly termed as iron phosphate, aluminum phosphate and calcium phosphate. Since the forms of inorganic phosphorus have a closed relationship to the availability of phosphorus in the soils, it seems necessary to study the forms of inorganic phosphorus by use of the solubility-pH curves as used by previous workers.

## REVIEW OF LITERATURES

Fraps (1906) studied the solubility of different phosphatic minerals in dilute acid and reported that precipitated phosphates of calcium, aluminum, and iron as well as apatite, vivianite and triplite can be dissolved in 0.2 N nitric or hydrochloric acids.

Stoddart (1909) showed that wavellite and dufrenite were dissolved by sodium hydroxide.

Williams and Dean have shown that the phosphorus in iron and aluminum phosphate minerals is nearly completely soluble in NaOH, whereas that in apatite or rock phosphate is practically insoluble.

Russell (1932) indicated that inorganic phosphorus in neutral soils is probably a calcium phosphate or hydroxy-apatite and in acid soils is presumably in combinations with iron and aluminum oxides.

McGeorge indicated that in alkaline calcareous soils the phosphate solubility is at a minimum within the range 7.6 to 8.5, and increases beyond this on both acid and alkaline soils.

Garner and Kelley (1940) presented the solubility curves for phosphate in various Colorado soils. All the curves were of the same general type, with a minimum solubility near pH 7 to 8, and an increasing solubility at higher or lower pH values.

According to the results of the study of solubility curve of phosphate minerals by Stelly and Pierre (1942), rock phosphate and apatite were found to be highly

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soluble in acid solutions and relatively insoluble at pH values near above neutrality. Aluminum phosphate minerals such as variscite and wavellite phosphorus are very highly soluble at high pH values and moderately soluble at pH values below 4.0, and least soluble at about pH 5 to 6. Iron phosphates such as vivianite is highly soluble at both high and low pH values and have a narrow pH range over which the solubility is very slight. The dufrenite shows a lower phosphorus solubility and a wider pH range of minimum solubility than the vivianite.

## MATERIALS AND PROCEDURE

Soil samples were collected from paddy soils of six main soil groups in Taiwan. The soil samples are air-dried and screened through a 1 mm. sieve. The general chemical properties of the soil samples are shown in table 1.

Table 1. Description and chemical properties of the paddy soils

| Sample No. | Sampling Localities | Soil Group | Soil Texture | pH | 0.002 N $H_2SO_4$ Soluble P ppm |
|---|---|---|---|---|---|
| 2033A | Chunglee | Red Earth | Loamy Clay | 4.2 | 6 |
| 2033B | Chunglee | Red Earth | Clay | 4.0 | 29 |
| 2094A | Lalee | Red Earth | Clay Loam | 5.0 | 10 |
| 2094B | Lelee | Red Earth | Loamy Clay | 6.1 | 6 |
| 2053A | Kung Kuang | Red Earth | Loam | 4.6 | 7 |
| 2053B | Kung Kuang | Red Earth | Loamy Clay | 4.6 | 2 |
| 3010A | Chung liao | Yellow Earth | Clay Loam | 5.4 | 26 |
| 3010B | Chung liao | Yellow Earth | Clay Loam | 6.2 | 24 |
| 1029A | Shize | Yellow Earth | Clay Loam | 4.6 | 11 |
| 1029B | Shize | Yellow Earth | Loam | 5.8 | 3 |
| 1026A | Tanhui | Sandstone and Shale Alluvial Soil | Loamy Clay | 5.7 | 36 |
| 1026B | Tanhui | Sandstone and Shale Alluvial Soil | Clay | 7.2 | 14 |
| 1004A | Hsing Drong | Sandstone and Shale Alluvial Soil | Silty Clay Loam | 5.4 | 59 |
| 1004B | Hsing Drong | Sandstone and Shale Alluvial Soil | Silty Loam | 5.6 | 41 |
| 2053A | Hou lang | Sandstone and Shale Alluvial Siol | Sandy Loam | 5.4 | 34 |
| 2053B | Hou lang | Sandstone and Shale Alluvali Soil | Loam | 5.7 | 33 |
| 3017A | Peidau | Slate Alluvial Soil | Silty Clay Loam | 7.1 | 70 |
| 3017B | Peidau | Slate Alluvial Soil | Loamy Clay | 7.3 | 40 |
| 5083A | Pingtung | Slate Alluvial Soil | Sandy Loam | 6.4 | 86 |
| 5083B | Pingtung | Slate Alluvial Soil | Silty Loam | 7.5 | 43 |
| 7001A | Hwaliang | Schist Alluvial Soil | Sandy Loam | 7.2 | 33 |
| 7001B | Hwaliang | Schist Alluvial Soil | Silty Loam | 7.2 | 28 |
| 4049A | Linfunzing | Mudstone Alluvial Soil | Silty Clay Loam | 4.8 | 5 |
| 4049B | Linfunzing | Mudstone Alluvial Soil | Clay | 4.5 | 2 |
| 0608A | Tung Hse | Saline soil | Sandy Loam | 7.8 | 31 |
| 0608B | Tung Hse | Saline soil | Sandy Loam | 8.1 | 21 |

| | | | | | |
|---|---|---|---|---|---|
| 0403A | Jang zung | Saline soil | Sandy Loam | 7.9 | 86 |
| 0403B | Jang zung | Saline soil | Loamy Clay | 7.6 | 41 |

* A=Surface Soil, B=Subsoil

The procedure used to determine the solubility of inorganic phosphorus at various hydrogen-ion concentrations was following the method of M. Stelly and W. H. Pierre (1942).

One gram sample of air-dried soil was added to 100 ml of solution containing various proportion of 0.10 N hydrochloric acid or 0.10 N sodium hydroxide in a 250 ml glass bottle. The bottles were shaken for 8 hours in an end-over-end shaker and allowed to stand for 16 hours at room temperature.

A part of suspensions were used to determine pH with glass elctrode. The suspension was then centrifugied and filtered. Phosphorus in the filtrate was determined colorimetrically by the method of Troug.

## RESULTS AND DISCUSSION

The solubility curves of inorganic phosphorus of soils of the red earths are represented graphically in Fig. 1. to Fig. 3.

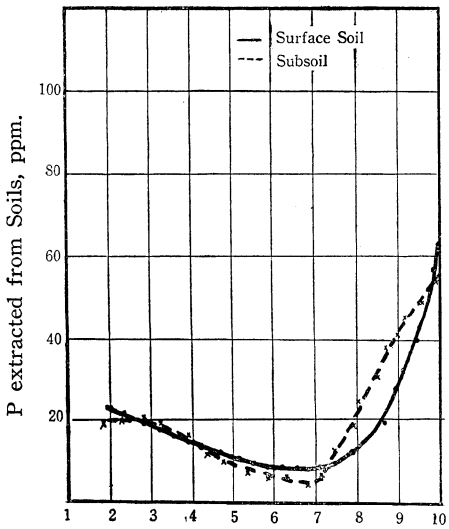


Fig. 1. Phosphorus extracted at various pH values from Chunglee soils.

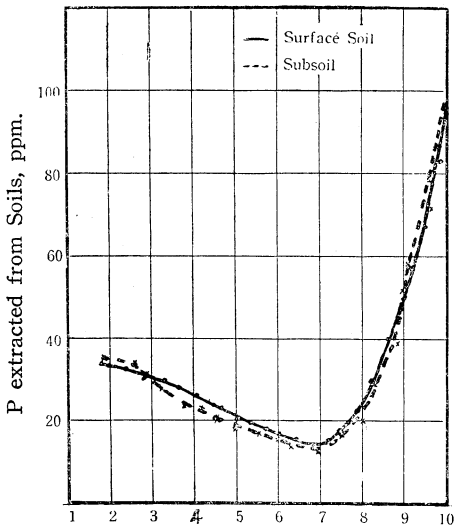


Fig. 2. Phosphorus extracted at various pH values from Lalee soils.

Similarly in all the three curves, the soil phosphorus has minimum solubility near pH 6.5 to 8. It increases rapidly on the alkaline side and moderately on the acid side.

The above phenomenon is true for both surface soils and subsoils.

The higher solubility of phosphorus on the alkaline side indicates the dominance of iron and aluminum phosphates present in these soils. The moderate solubility of phosphorus on the acid side suggests the presence of certain amount of calcium

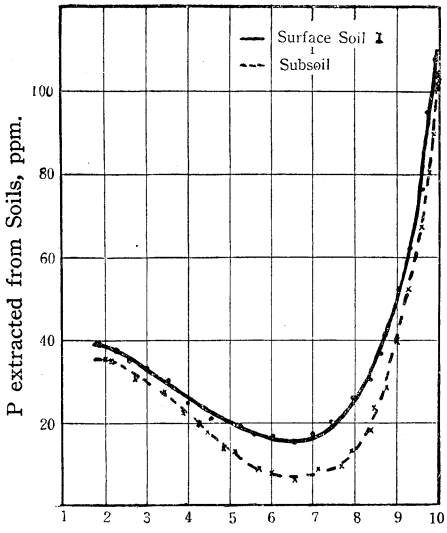


Fig. 3. Phosphorus extracted at various pH values from Kungkuang soils.

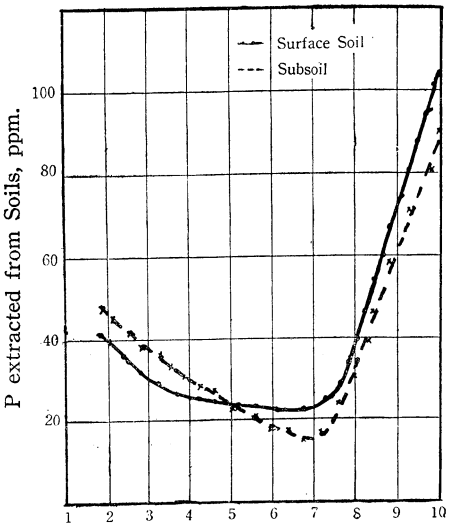


Fig. 4. Phosphorus extracted at various pH values from Chungliao soils.

phosphates.

The solubility curves of the two yellow soils (Fig. 4 and Fig. 5) are practically the same as those of the red soils except that the minimum solubility range of the surfacce soil of the yellow soils are wider than that of the red soils. It clearly indicates that some different species of iron or aluminum phosphate present in these two soil groups, possibly more dufrenite-like phosphate is present in the surface soil of the yellow soils.

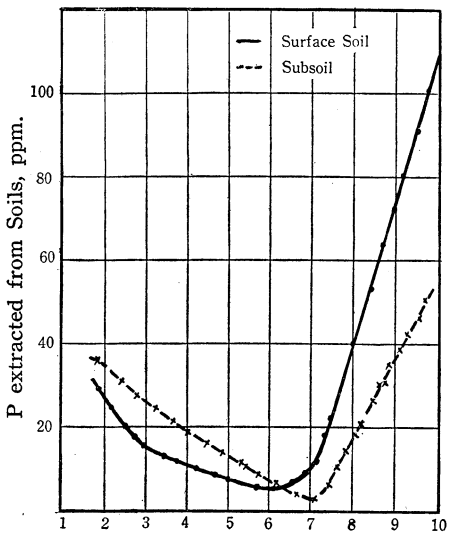


Fig. 5. Phosphorus extracted at various pH values from Shize soils.

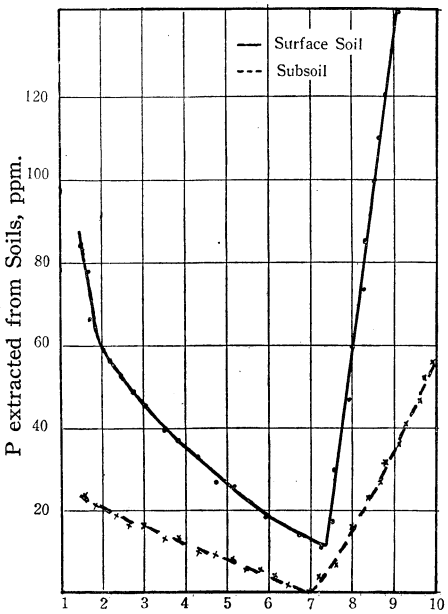


Fig. 6. Phosphorus extracted at various pH values from Tanhui soils.

For the sandstone and shale alluvial soils (Fig. 6–8), mininum solubility occurs at pH 7 and the solubility increases greatly on both sides of the neutrality. the shape of the curve suggests the presence of both iron, aluminum phosphate and calcium phosphate in about equal amount.

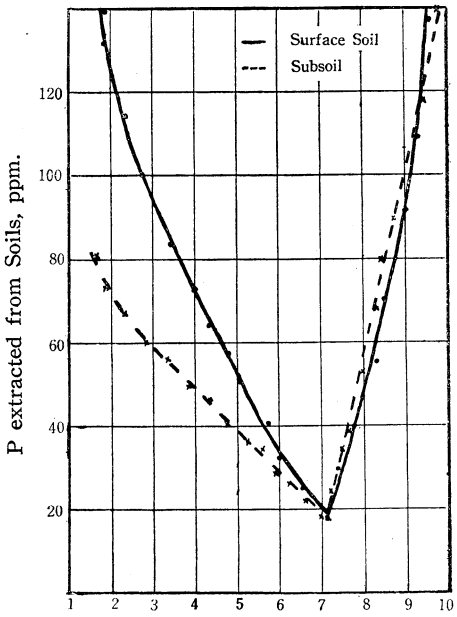


Fig. 7. Phosphorus extracted at various pH values from Hsingdrong soils.

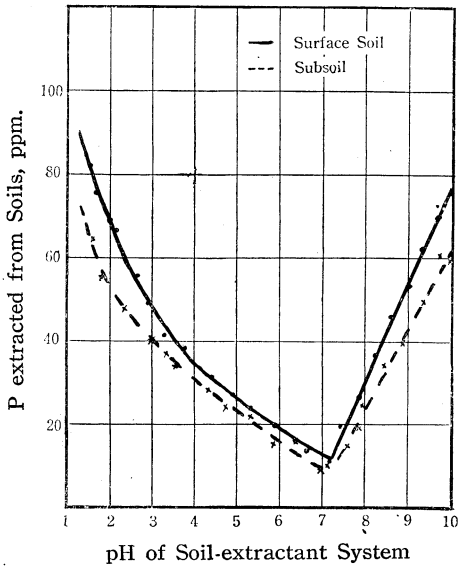


Fig. 8. Phosphorus extracted at various pH values from Houlang soils.

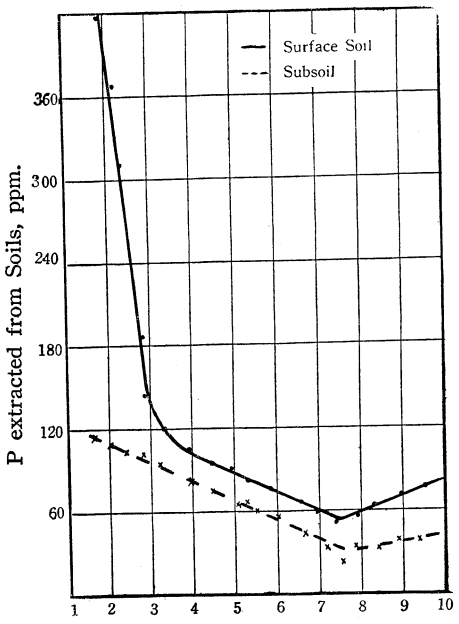


Fig. 9. Phosphorus extracted at various pH values from Peidau soils.

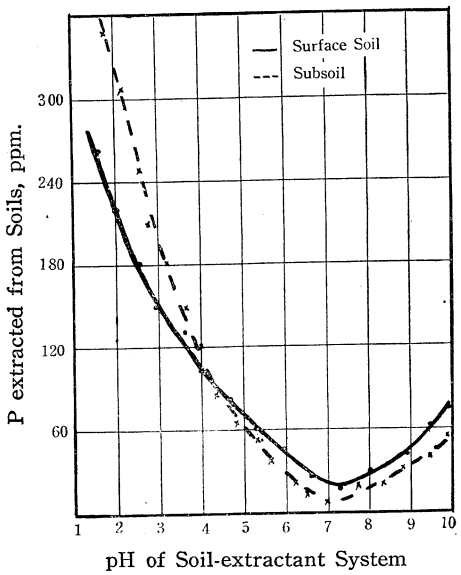


Fig. 10. Phosphorus extracted at various pH values from Pingtung soils.

The nature of the solubility curves of slate alluvial soils (Fig. 9–10) and schist alluvial soil (Fig. 11) is very similar to each other. Contrary the red and yellow soils, the solubility is higher on the acid side, particularly below pH 3. On the alkaline side, the curve only goes up a little. Obviously, calcium phosphates are predominant form of inorganic phosphate in the both calcareous soils. But a small amount of iron and alluminum phosphates are also present in these soils.

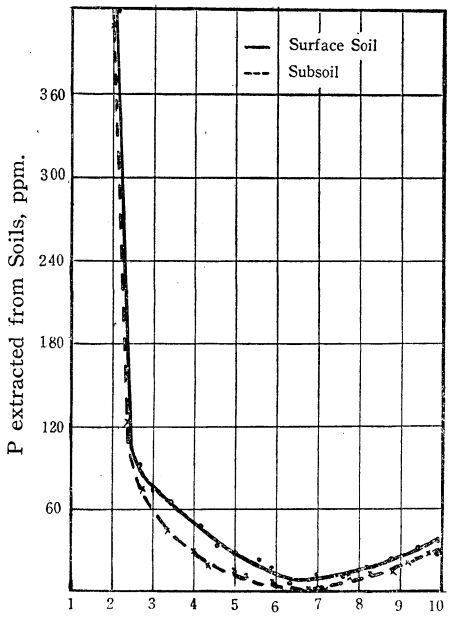


Fig. 11. Phosphorus extracted at various pH values from Hwa Liang soils.

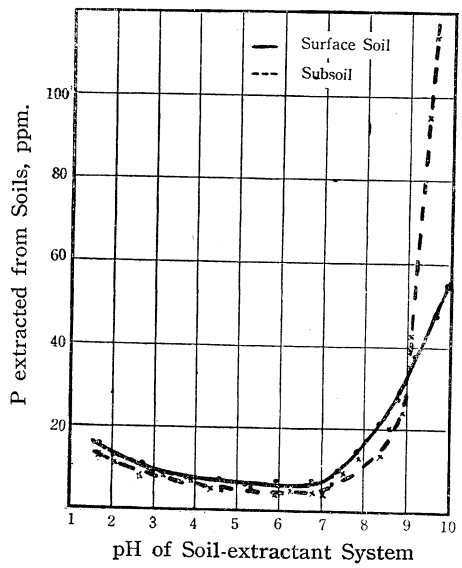


Fig. 12. Phosphorus extracted at various pH values from Linfunzing soils.

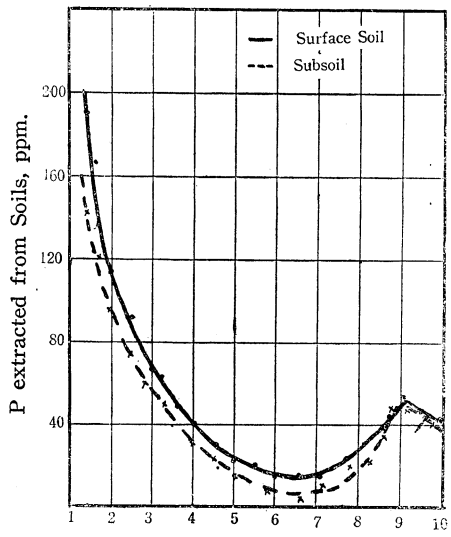


Fig. 13. Phosphorus extracted at various pH values from Tung Hse soils.

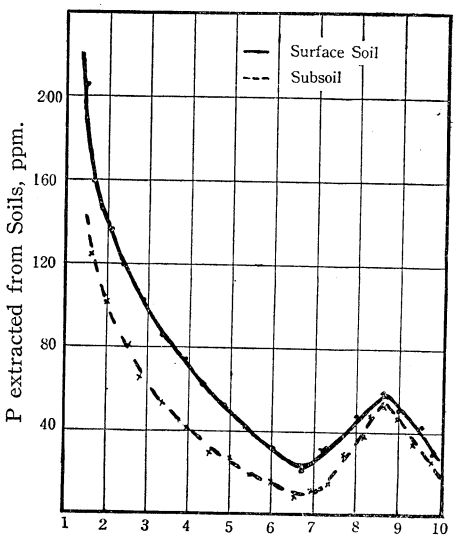


Fig. 14. Phosphorus extacted at various pH values from Jangzung soils.

For the mudstone alluvial soil (Fig. 12), the nature of the solubility curve is similar to those of the yellow soils. The solubility is higher on the alkaline side and lower on the acid side. It is believed that iron and aluminum phosphate is the main form in this soil.

Fig. 13 and Fig. 14 are the solubility curves of saline alluvial soils. The shapes of curves are very close to those of the slate and schist alluvial soils, except that the solubility increases from pH 7 to 8.5 and decreases again above pH 8.5, thus forming a small peak at pH 8.5–9. The predominent forms of phosphate in these soils similar to those in slate and schist alluvial, but presumably more soluble calcium and magnesium renders the solubles phosphate reprecipitate at the strongly alkaline reaction.

Chang and Jackson (1957) found that iron, aluminum and calcium phosphates can coexist in a soil with a reaction from acid to alkaline. Chang and Chu (1960) fractionated the inorganic soil phosphorus into the total amount of each discrete chemical form and concluded that there are three distribution paterns of inorganic phosphorus in representative Taiwan soils, namely, iron-phosphate dominating type, calcium-phosphate dominating type and iron-calcium phosphates dominating type. The data in this paper qualitatively supports the above findings.

## SUMMARY

The pH-solubility curve of inorganic soil phosphorus of the main soil groups of Taiwan was summarized as follows:

(1) In the acid red earth or yellow earth and mudstone alluvial soil, iron and aluminum phosphate may be the principal form of phosphorus.

(2) In the slate alluvial soils, schist alluvial soils and saline alluvial soils, calcium phosphate is predominent form of inorganic soil phosphorus.

(3) In the sandstone and shale alluvial soils, both calcium phosphate and iron, aluminum phosphates are present in about equal amount.

(4) The minimum solubility of phosphorus in the soils of different soil groups are generally in the pH range of 6 to 8.

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# 臺灣稻田土壤無機磷酸之可溶曲線之研究

曾　憲　鼎

## 摘　要


臺灣主要土類之土壤中無機磷酸之 pH-可溶性曲線之研究摘要如下：

(1) 在酸性之紅黃壤，泥岩冲積土，磷酸鐵鋁可能爲土壤中磷酸之主要形態。

(2) 在粘板岩冲積土壤，結晶片岩冲積土壤及鹽土，磷酸鈣爲主要之無機磷酸型態。

(3) 在砂頁岩冲積土中，磷酸鈣及磷酸鐵鋁約有相同之數量。

(4) 在不同土類之土壤中，無機磷酸最低可溶性通常在 pH 6 至 8 之範圍內。